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New Brunswick Environmental Trust Fund Project

Improving Water Quality Through Constructed Wetlands

Final Report

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Submitted by

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Abstract

We undertook a 3 year study of the use of constructed wetlands to treat storm water in Centennial Park, Moncton, New Brunswick. Water flowed through the wetlands for the first time in year two of the study. In general the wetlands were successful in reducing turbidity, heavy metals and *E. coli*. However, despite reductions, many *E. coli* samples exceeded the recommended 200 organisms per 100 ml. In addition, all samples involving cadmium were in exceedance of the recommended guideline for recreational water. We therefore feel that it is important to sample the first settling pond in the wetlands every 5 years and if necessary remove and treat the sediments. Since we observed overflow of the wetlands on a number of occasions, we recommend that careful attention be paid to the possibility of storm events during the lifespan of the wetlands. The receiving waters, Jonathan Creek, showed an improvement in the water quality downstream of the wetlands as indexed by an increase in the number of pollution intolerant macroinvertebrate species.

Introduction

In October of 2001, the City of Moncton undertook the construction of wetlands in Centennial Park, Moncton, NB, Canada, as a means of treating storm water before release into Jonathan Creek (Figure 1). A series of eight interconnecting deep-water marshes interspaced with five shallow-water marshes were excavated and vegetated with a succession of plants based upon location in the marsh (Figure 2). Storm water flowed into the marshes for the first time in the spring of 2003. A research group formed of four professors from the Université de Moncton and a research partner from the Canadian Wildlife Service, partnered with the City of Moncton to provide support for bio and physical monitoring of the effectiveness of the marshes in dealing with storm water contaminants and to provide recommendations for improvements to the system. The secondary objectives of the project were:

1) to evaluate improvement in water quality resulting from the construction of the wetlands in Centennial Park, Moncton,
2) to measure and evaluate physical and biological changes in both the wetlands and in the receiving waters of Jonathan Creek,
3) to evaluate improvement in Jonathan Creek using fish and macroinvertberates as biological indicators,
4) to provide information that will assist other communities in evaluating this technology and,
5) to contribute to the ongoing efforts to improve water quality in Jonathan Creek.

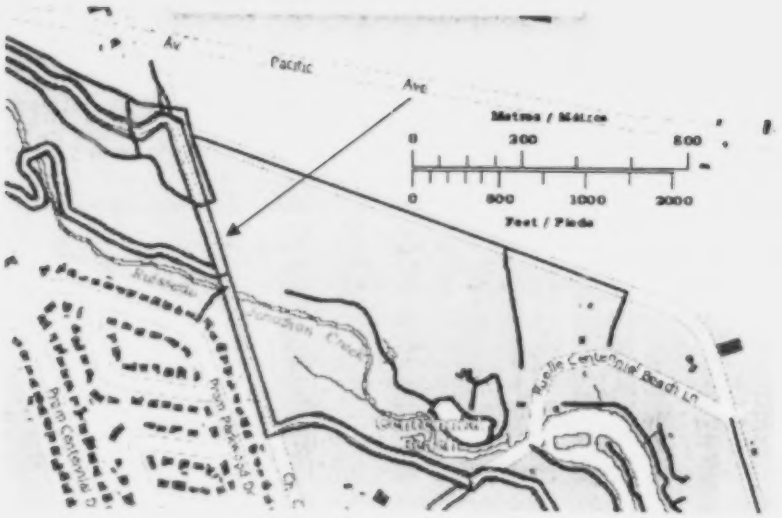

Figure 1. Centennial Park. Located in Moncton, New Brunswick. Arrow indicates location of wetlands.

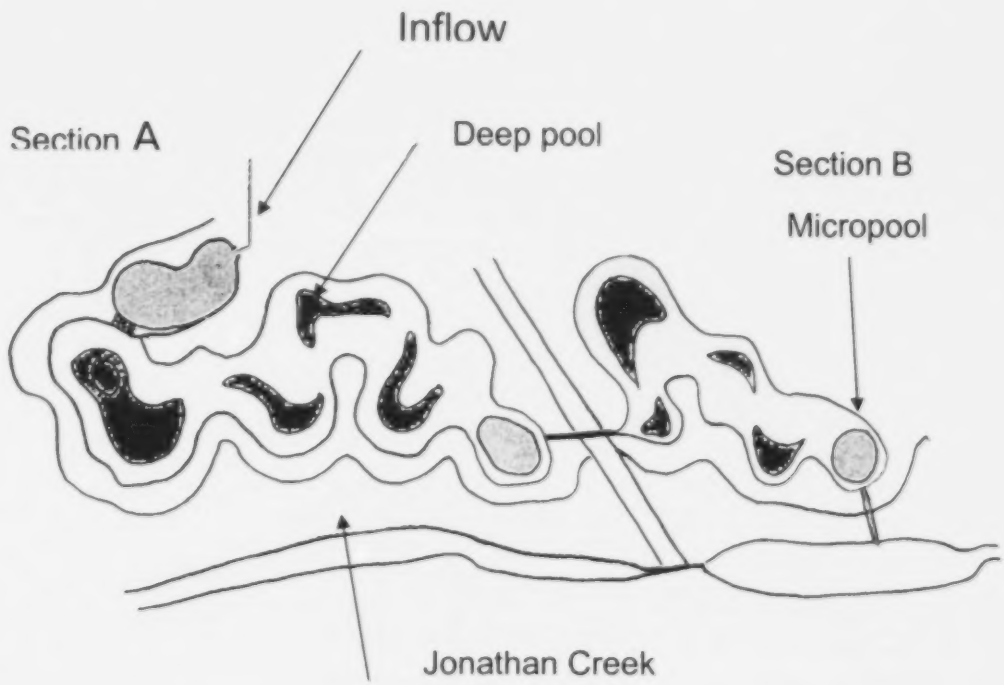

Figure 2. Overview of the wetlands located in Centennial Park, Moncton.

This report contains results from the first year of construction and the following 2 years of operation of the wetlands. We wish to acknowledge the support of New Brunswick Environmental Trust Fund (NBETF) that provided us with critical financial support. Over the past three years this project has received support from the HRDC's Summer Career Placement Program and in kind support from the research partners, in particular Environment Canada that paid for the analysis of water and sediments. We set out several measures of annual success as stipulated in our NBETF application:

1) collection of data and documentation of results as described and submission of yearly, reports.
2) refinement of the project and learning through sharing of information among the partners and,
3) collective interest by the public in the project.

Overview of accomplishments

Sampling was carried out at: 1) the inflow pipe runoff (added in 2004), 2) the inflow into the wetlands, 3) the midway point through the wetlands, 4) the outflow, 5) upstream from the outflow and 6) downstream from the outflow. At these sites the following were assessed:

☑ pH, temperature, oxygen (mg/L), conductivity (µS), turbidity (NTU), *E. coli* and total coliforms (17 times in 2003 and 16 in 2004)

☑ major ions, sediments and heavy metals at all sites (Environment Canada)

☑ heavy metals in cattails tubers at the inflow, the midway point and the last pond in the wetlands at the end of the studies (Environment Canada)

☑ 8 mm+ rain event from July 13 to July 16, 2003, where water samples were analyzed for pH, temperature, oxygen (mg/L), conductivity (µS), turbidity (NTU), heavy metals, nutrients, *E. coli* and total coliforms. Samples were taken before the rain, every six hours during the rainfall and once a day for three days following the cessation of rain.

☑ open house day was held onsite at the wetlands each year. The event was previously announced in the Times and Transcript. In 2004, an article on the project was published in the Times and Transcript

☑ photographic record and vegetative survey of wetland development at the beginning of the studies

☑ macroinvertberate collection upstream and downstream from the outflow

☑ electrofishing conducted upstream and downstream from the outflow on October 7, 2003. High water that persisted for an entire week in 2004 prevented electrofishing during dates similar to 2003.

☑ bird observations during the summer and fall of 2003 and 2004.

Introduction

What is a constructed wetland?

Constructed wetlands are a water quality best management practice (BMP) designed to enhance storm water quality that has been contaminated as a result of urbanization and development (Anonymous 2004). They are engineered aquatic ecosystems specifically designed to remove pollutants by optimizing physical, chemical and biological processes that occur in natural wetlands (Jin *et al.* 2003).

What do they treat and why use them versus conventional methods?

Constructed wetlands use biological processes that occur in nature to reduce the principal contaminants found in urban runoff before they reach critical habitats. They have been shown to decrease the levels of suspended solids, oxygen-demanding substances, metals, pathogens, pesticides, hydrocarbons, and trash or debris (McBrien 2000).

Compared to conventional water treatment methods, constructed wetlands have numerous benefits. Aside from naturally cleansing stormwater in an aesthetically pleasing manner while adding additional wildlife habitat, constructed wetlands have a direct monetary value. Compared to mechanical treatment of stormwater, the initial construction costs for constructed wetlands is on the average 60 – 90 percent less while operation and maintenance costs is on the average 95 percent less (Anonymous 1996). Other advantages include operational low energy consumption, flood protection, reduction of erosion, noise and energy pollution, green house gas absorption, air purification, and educational and recreational opportunities.

How do they function?

The primary function of wetlands is the slowing of water flow to promote sedimentation (Reagin 2002). Vegetation is the second most vital feature of a wetland. The plants trap sediments with their roots and branches where associated microbes metabolize the nutrients. Besides housing and nourishing these beneficial microbes, plants provide additional surface area for absorption and uptake of nutrients and heavy metals, and they prevent substrate compaction (Sauter and Leonard 1997). Shallow depths also aid in adsorption and decomposition of problematic constituents by increasing contact with bottom sediments (WRP 1993). Even the sun is incorporated into wetland design,

reducing pathogens by destroying their cell walls (photolysis) (Reagin 2002). Other pollutant removal processes include filtration, precipitation and vaporization (Geary *et al.* 2003).

What are the concerns?

It is well known that plants will uptake metals, thereby presenting a potential risk of bioaccumulation in the food chain. If the wetland vegetation is accumulating metals to toxic levels, the symptoms may not be apparent as aquatic plants show greater resistance to the negative effects of heavy metals compared to terrestrial plants (Staelens *et al.*, date of publication unknown). Ongoing monitoring is necessary to establish if there is subsequent transmission to wildlife. Studies have also shown metal accumulation and toxicity in fish and other aquatic organisms. In several cases, mammals, especially near point sources, have been found with elevated tissue levels of metals, however, the literature has not established conclusive evidence as to the danger of bioaccumulation in constructed wetlands.

The possibility that the wetlands might become saturated with pollutants and lose their effectiveness is a concern, though a typical lifespan of 10 to 15 years is expected. The wetlands in Centennial Park were specifically designed with a settling pond at the head to reduce infilling of the remaining ponds and allow for periodic removal of potentially contaminated sediments.

Since the main function of the wetlands is the settling of suspended solids and associated pollutants, reduction of scouring and resuspension of sediments are crucial. During the past two years of observations we witnessed complete overflow of the wetlands and an erosion gully at the entrance to the wetlands (Figures 3 and 4). Future designs will have to pay close attention to the possible magnitude of rainfall events during the lifespan of the wetlands to avoid similar occurrences.

The effectiveness of the wetlands in winter has also been questioned, yet EPA has determined that wetlands can still be effective if area and residence time is increased to counter the slowing of biological processes (Reagin 2002).

Figure 3. Sediment deposit from erosion at the inflow.

Figure 4. Overflow of wetlands during a rainstorm in August 2004.

Wetland Survey

The species of vegetation planted in the wetlands are listed in Table 1. Not all of the species in Table 1 were present within each basin. Details are available from the City of Moncton or from Dr. Alyre Chiasson. Surrounding native plants also rapidly took root. In 2003, survey transects were placed through all five of the shallow-water marshes. At one meter intervals, a square meter of area was sampled. The number of plants were counted or estimated, area occupied by species within the one meter area estimated, and plants identified to species, or coded and individually pressed for later identification. Various species of grasses not within Table 1, covered 40% of survey transects while cattails covered 20%. A visual vegetative survey was conducted in 2004 to determine which species contributed to the final composition irrespective of those initially planted (Table 1). Common cattail dominated the wetlands in 2004 and arrowhead thrived, reaching great heights (Figure 5). While most species planted in the wetlands survived, sun damage and flooding drastically affected many of the shrubs in the buffer zone.

Only casual observations of wildlife were made. Mallard ducks were frequent visitors to the wetlands and as many as seven were seen on a single day. During the fall of 2003, two greater yellowlegs were spotted on separate occasions. Although never sighted, evidence of muskrats was also observed. Fish were sighted in the ponds as well, however, only Jonathan Creek was electrofished. The electrofishing results conducted on October 7, 2003 can be found in Table 2. As found in 2002, species diversity and numbers were exceedingly low. No salmonids were captured. However, summer temperatures in the

creek approached lethal levels for brook trout (Table 3. Appendix). Electrofishing was not conducted in 2004 due to high water levels.

Figure 5. Arrowhead, August 2004.

Table 1. Species of plants planted in 2003 and remaining in 2004.

Wetland Plants			Wetland A		Wetland B	
	Scientific Name	Common Name	Planted	Present	Planted	Present
	Typha latifolia	Common Cattail	X	X	X	X
	Scirpus acutus	Hardstem Bullrush	X	X	X	X
	Equisetum fluviatile	Water Horsetail	X		X	
	Ceratophyllum demersum	Coontail	X	X	X	X
	Sagitaria latifolia	Duck potatoe, Arrowhead	X	X	X	X
	Pontedaria cordata	Pickerel Weed	X	X	X	
	Nymphoide cordata	Floating Heart	X	X		
	Nymphea odorata	White Water Lilly	X			
	Lemna minor	Duckweed	X	X		
Shrubs						
	Cornus stolonifera	Red-twig dogwood	X	X	X	X
	Viburnum trilobum	Cranberrybush Viburnum	X	X	X	X
	Sambucus canadensis	American elderberry	X	X	X	X
Deciduous Trees						
	Fraxinus americana	Ash	X	X	X	X
	Acer saccharinum	Silver Maple	X	X	X	X
	Betula nigra	River Birch	X	X	X	X

Table 2. Fish captured on October 7, 2003 in Jonathan Creek.

Downstream of wetland outflow (182 m^2)

White sucker (*Catostomus commersoni*) 3

Creek chub (*Couesius plumbeus*) 9

Threespine stickleback (*Gasterosteus aculeatus*) 2

Ninespine stickleback (*Pungitus pungitus*) 1

Upstream of wetland inflow (142 m^2)

White sucker (*Catostomus commersoni*) 1

Creek chub (*Couesius plumbeus*) 29

Physical water chemistry results

The 2003 and 2004 monitoring results for water quality can be found in Table 1 (Appendix). The Canadian Guidelines for Recreational Water Quality and the Canadian Guidelines for the Protection of Aquatic Life were used as a base of reference for determination of exceedance levels (http://www.ec.gc.ca). It should be noted that recreational activities occur several hundred meters further downstream from the outflow to the wetlands in what is referred to as the Centennial Park Pond (canoeing, paddle boats).

In 2003, air temperature was nearly identical for all sites over any given day, but the trend over time was quite variable. The 2004 air temperature data was more variable between sites, but showed a fairly linear decrease in temperature over time.

Even though wetland inflow water temperature was nearly always lower than Jonathan Creek in 2003, the outflow was always higher (by 0.4 to 6°C); an increase from the inflow of 1.2 to 9°C (Figures 6 and 7). Even with this warm water flowing into the creek, over 80% of the upstream temperature readings in the creek were higher than downstream (-0.9 to 2°C difference). The wetland inflow was always warmer than the upstream sampling site in the creek (by 0.4 to 6°C) in 2004. The 2004 outflow temperature was higher than upstream (up to 0.5 to 3.2°C) for all days except three where it was lower by 0.1 to 0.3°C. There was very little difference in temperature between the upstream and downstream sites in the creek in either year (-0.9 to 0.2°C).

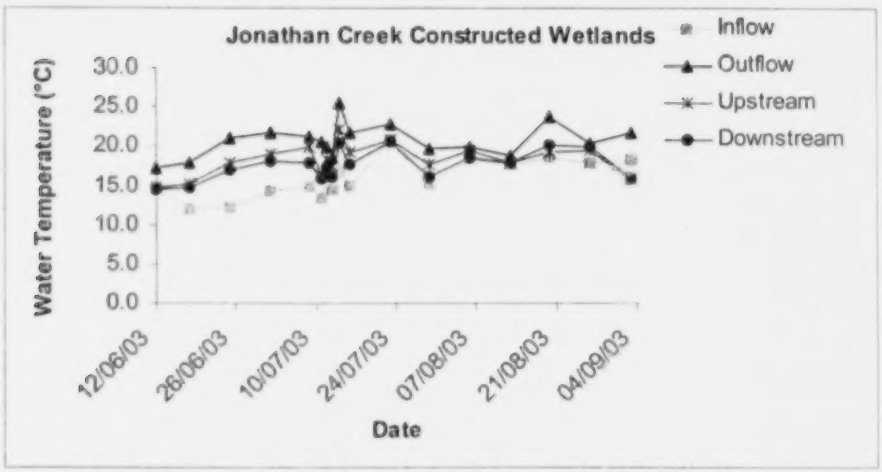

Figure 6. Water temperature readings taken at the inflow and outflow sites within the constructed wetlands and the upstream and downstream sites in Jonathan Creek from June 12 to September 04, 2003.

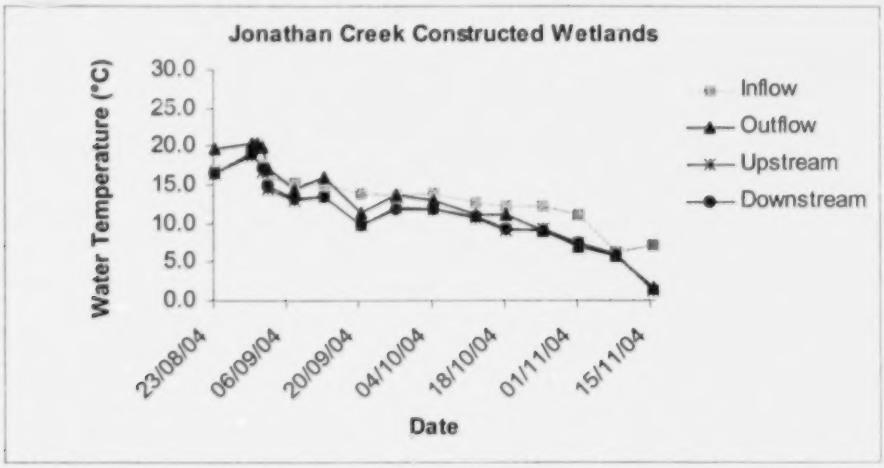

Figure 7. Water temperature readings taken at the inflow, outflow, upstream and downstream sites from August 23 to November 15, 2004.

On July 23, 2003, several sites had pH values that exceeded the recommended level of 9 for the protection of aquatic life (9.2 to 9.7) (Table 3, Appendix). Values above 9.5 can be harmful to adult brook trout (*Salvelinus fontinalis*), though no brook trout occur in the creek immediate to the wetlands. The two highest values of pH were associated with the upstream and downstream sampling sites in the creek. Whereas, the marsh ponds by their nature provide unsuitable habitat for brook trout, the same cannot be said for a healthy creek. The 2004 data had no occurrences of high alkalinity (Figure 8). Both years show

that the wetlands have a neutralizing effect on the alkaline inflow (as much as a decrease of 1 pH unit). Although the pH of the wetland outflow was reduced, in 2003, it was still higher than the upstream creek site, 85% of the time (max. increase of 0.4 pH units). This input was associated with either no change or a slight increase in pH in the creek downstream (max. difference of 0.2). Even though the 2004 wetland inflow had a higher pH than upstream in the creek, the outflow was always lower (as much as 0.7).

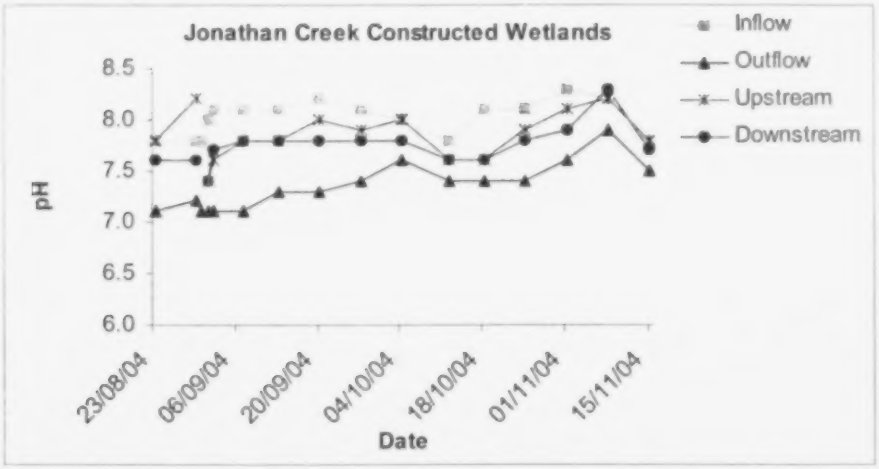

Figure 8. pH readings for the year 2004.

Low oxygen concentrations (below 4.6 mg/L) were observed at the wetland outflow on July 13, 14, August 6 and 20, 2003 (Figure 9). No cases of low oxygen of this magnitude were observed at the outflow in 2004 (Figure 10). This is of little concern for Jonathan Creek as the outflow of somewhat anoxic water at this time of year into the creek would have been minimal, but within the marshes this may inhibit growth of aerobic bacteria leading to purification of organic matter. Since the period in question is relatively short, the overall impact is probably minor.

Over 80% of the sampling dates in 2003, and all but one in 2004, showed a drop in oxygen levels from the inflow to the outflow. A decrease in oxygen greater than 35% occurred on 65% of the dates in 2003, but not once in 2004 (Figures 9 and 10). Compared to the upstream sampling site in the creek, the wetland outflow was lower in dissolved oxygen for all dates in 2003 and 2004 with the exception of three dates. The lower oxygen input had little affect downstream in the creek in 2004 (decreased in comparison with upstream from 0 to 0.7 mg/L). Conversely, in 2003, over 75% of the data showed increases in dissolved oxygen downstream (3 to 5.5 mg/L, 35 to 40%).

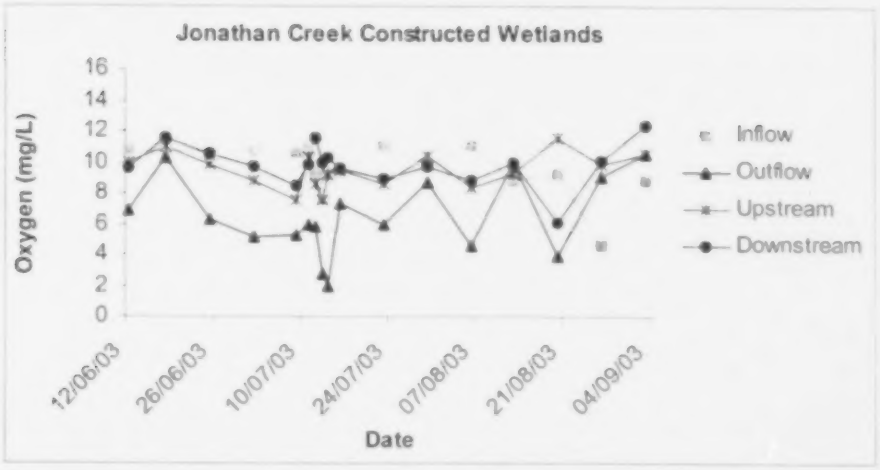

Figure 9. Dissolved oxygen readings for the year 2003.

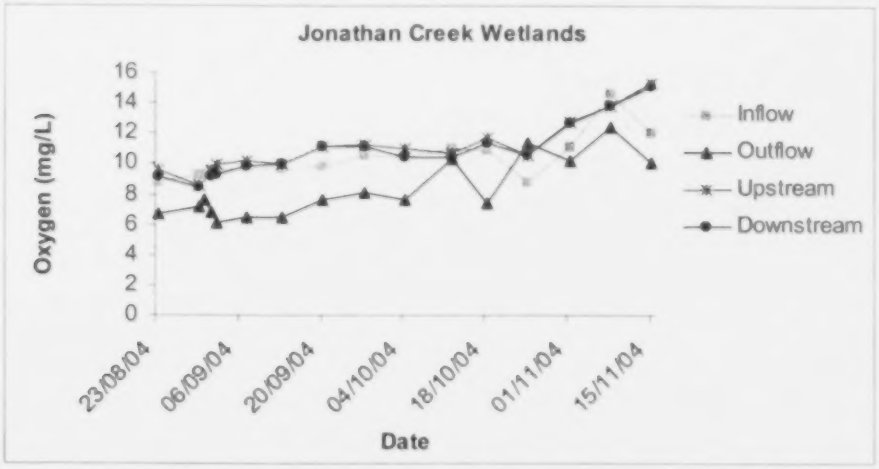

Figure 10. Dissolved oxygen readings for the year 2004.

There is no listing in the Environment Canada Water Quality Guidelines for levels of turbidity for aquatic life; however, 50 NTU is suggested for recreational water. Throughout the summer of 2003 there were spikes of turbidity well in excess of this value (> 300 NTU). However, on the same sampling dates, all sites were neither consistently high nor low, suggesting that the phenomena may have been unique to the sampling sites themselves. Conceivably, in the wetlands, turbidity may be wind induced with basins of various degrees of exposure. In addition, there was no association, in either year, between turbidity levels at the outflow of the wetlands or values observed either upstream or downstream in the creek (Figure 11).

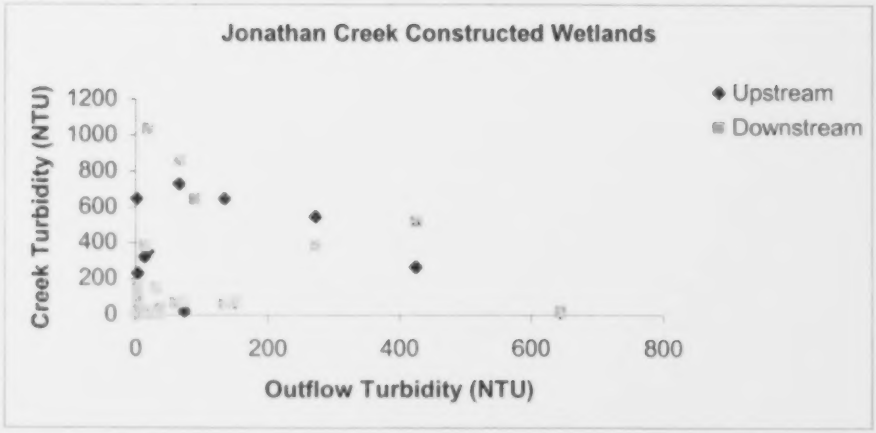

Figure 11. Turbidity reading observed upstream and downstream in Jonathan Creek plotted against turbidity at the outflow of the wetlands for both 2003 and 2004.

The wetland outflow had lower turbidity than the inflow 65% of the time in 2003 and 50% in 2004. The outflow readings were higher than the site located upstream in the creek 41% of the time in 2003 and 75% in 2004. Downstream turbidity was greater than upstream 70% of the time in 2003 and 56% in 2004. The inflow turbidity was lower than the inflow pipe 75% of the time. The recommended limit of 50 NTU was exceeded 7 times at both the inflow and outflow in 2003, but in 2004 fell to 4 and 3 respectively. The upstream and downstream sites in the creek had 9 and 10 incidents above 50 NTU in 2003, but only 3 and 4 respectively in 2004. In total, 2003 had twice as many exceedances than 2004. The 2003 data had 23 turbidity values over 200 NTU, while the 2004 data only had 4. The difference between the inflow and outflow varied to a much greater extant in 2003 compared to 2004. We believe that this is attributable to the extensive erosion caused by inflow water traversing the forest floor before reaching the wetlands.

Heavy metals need to be closely monitored because of their toxicity at low concentrations. While cadmium was always above the Canadian Water Quality Guidelines for Recreational Waters, levels of arsenic, chromium and cobalt were always well below for both years of the study (Table 4). The number of limit exceedances for copper, lead and zinc were all reduced from the inflow to the outflow for both years (Figure 12. Appendix). Aluminum had a 100% reduction to guideline concentrations from the inflow to outflow in 2003, but was increased from 83% exceedance to 100% in 2004. The amount of limit exceedances for Al, Cu, Pb and Zn were reduced or showed no change between upstream and downstream sites in either 2003 or 2004. Approximately, 1/3 to 2/3 of the wetland outflow samples had lower concentrations of the previous four heavy metals in comparison to the upstream site in the creek.

The fact that cadmium was always above the recommended levels should raise serious warning flags and be followed by further testing. Not only can Cd be very toxic to fish and benthic species at very low levels (Kehoe 1992), Cd has also been found to

accumulate in aquatic macrophytes, posing a threat to herbivores, and is the only metal that clearly accumulates with increasing age (Miller *et al.* 1983). Sources of Cd in stormwater include petroleum products and rubber (Whalen and Cullem 1988). On the other hand, the wetlands were very efficient in removing copper, lead and zinc. Research has shown a negative correlation between the concentrations of each of these three metals in sediment and species diversity index; Cu being the most detrimental (Baker and Yousef 1995). Copper in addition to mercury have been reported by some to be the most toxic metals to benthic organisms (Khangarot 1991). Though more toxic than Zn, Cu is more strongly adsorbed to organic matter and therefore less available for plant uptake (Emmerich et al. 1982). Sources of both Cu and Zn include petroleum products, antifreeze, brake linings, asphalt and concrete. Engine wear is an additional source of Cu, and sources of Zn also include undercoating, galvanizing and rubber (Whalen and Cullem 1988). While Pb, Cu and Zn have been shown to accumulate in fish, levels are usually not substantial enough to affect a consumer organism; bioaccumulation of organic contaminants is more likely to occur.

In 1995 the US EPA determined that the dissolved forms of heavy metals, as opposed to the particulate forms, should be regulated because even though total concentrations may be high enough to potentially affect aquatic life, most metals are in non-toxic particulate forms. Even the concentration of dissolved forms should not be the only consideration in evaluating the effects of heavy metals, time of exposure is also important (Lee and Jones-Lee, date of publication unknown).

Nutrients have been shown to be a major factor in raising biochemical oxygen demand (BOD) in aquatic environments. BOD is a measure of the amount of oxygen consumed by macroinvertebrates and bacteria in the decomposition of organic matter in streams (Fox and Absher 2002). As BOD increases dissolved oxygen decreases. Nutrients were measured on four dates from June 18 to July 16, 2003 and six times from August 30 to November 8, 2004 (Table 4). The wetlands were effective in reducing inorganic carbon, organic carbon and nitrogen (Figure 13. Appendix). The concentrations of these three nutrients were always lower at the wetland outflow than at the inflow in 2003. In 2004, outflow levels were lower than inflow levels 67% of the time for inorganic carbon, 83% for nitrogen and 50% for organic carbon. Nitrogen had removal efficiencies as high as 98%. In the creek, downstream values of nutrients never varied more than 1 mg/L compared to upstream samples.

Bacterial Contamination

One of the greatest impacts of urban stormwater runoff is high counts of fecal indicator organisms (Lee and Jones-Lee, date of publication unknown). According to The Environmental Protection Agency (EPA), non-point sources like urban and agricultural runoff contribute nearly 90% of the fecal coliform pollution found in surface waters (Kurz 1998).

Coliform and *E. coli* counts for 2003 and 2004(Coli Plate® method MPN) can be found in Table 6 (Appendix). The wetlands were effective at reducing total coliforms. Although 14 of the 17 dates sampled in 2004 had inflow coliform counts above the Coli Plate method's detection limit of 2424 organisms per 100 ml, 50% of the outflow samples showed a reduction to below the recommended level (Figure 14). It is difficult to quantify the removal capacity of the wetlands because so many samples surpassed the limit, however, total coliform reductions as high as 75% were witnessed (Figure 16).

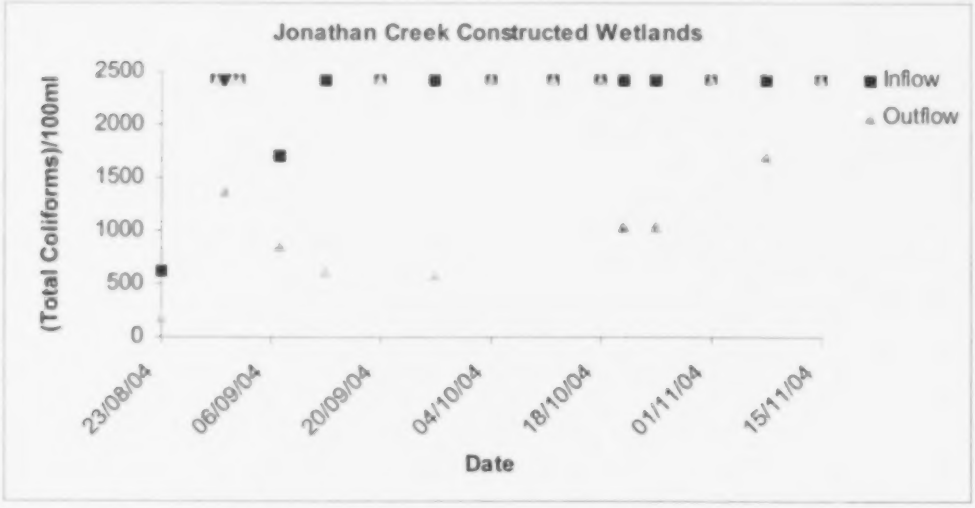

Figure 14. Most probable number of total coliforms per 100 ml for the year 2004.

The wetlands reduced the number of *E. coli* detection limit exceedances by 50% (from 4 to 2) in 2004 (Figure 15). Over 80% of the inflow samples had *E. coli* levels that exceeded the Canadian Water Quality Guidelines for Recreational Waters of 200/100 ml. A drop to below 200 *E. coli*/100 ml at the outflow of the wetlands was noted in approximately 65% of the samples with decreases ranging from 42 to 94% of inflow levels (Figure 16).

There were concerns that stormwater entering the wetlands might pick up bacteria from running across the forest floor from the inflow pipe to the first pond in the wetlands, Though there were two cases of increases for both coliforms and *E. coli*, 60% of the samples showed a decrease in the number of *E. coli*, as high as 95%. In a number of samples the reduction could not be determined because levels were always in excess of the detection capacity of the Coli Plate method.

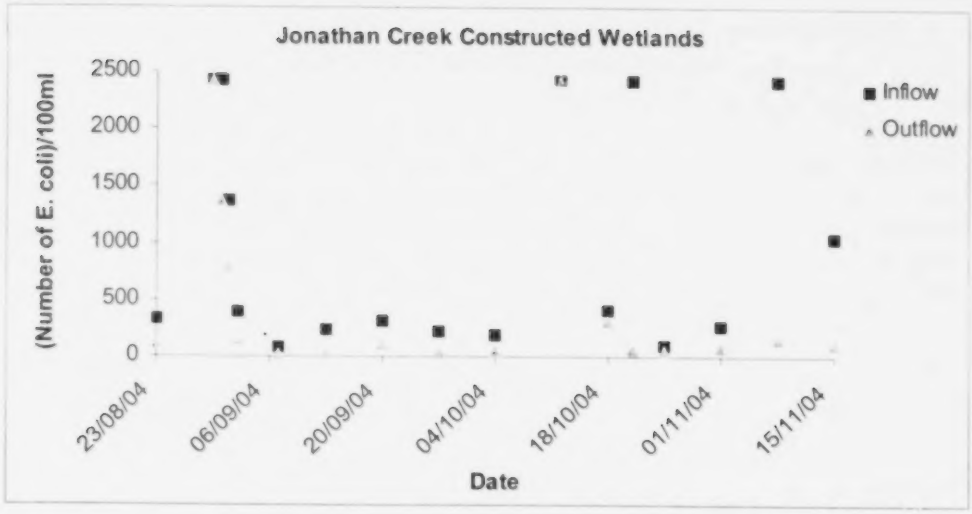

Figure 15: Most probable number of *E. coli* per 100ml for the year 2004.

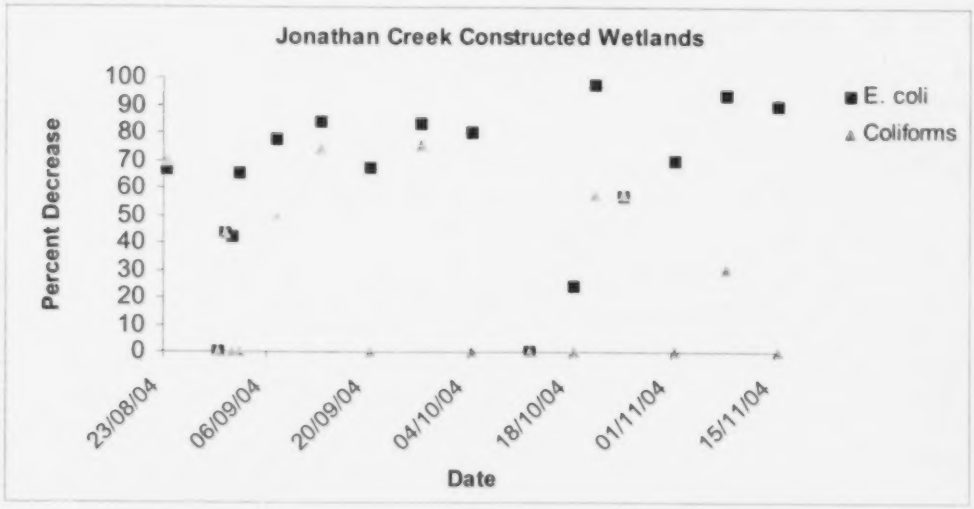

Figure 16: Percent reductions of total coliforms and *E. coli* from the inflow to the outflow for the year 2004.

The 2003 study showed similar coliform and E. coli reduction trends, but to a lesser extent. Of the 13 water samples taken from June 18 to August 6, 2003, the inflow had ten coliform and five *E. coli* samples above the detection limit, while the outflow had 11 and four respectively (Figures 17 and 18). In 2003, the inflow *E. coli* levels exceeded the acceptable limits of 200 *E. coli*/100ml 69% of the time, with a 33% reduction in

exceedances at the outflow. Compared to the 2004 data, which always showed reductions in both coliforms and *E. coli* from the inflow to the outflow, the 2003 data had two cases of increases for each, all on different dates.

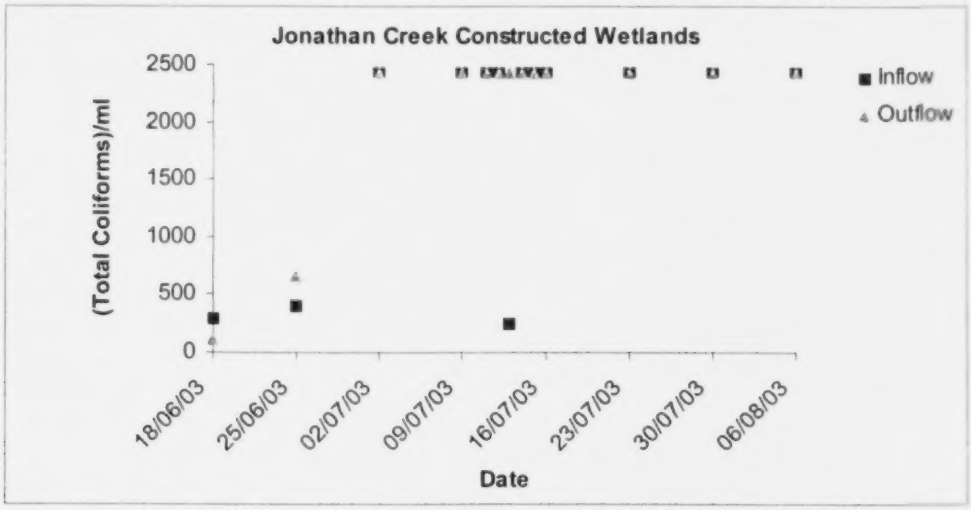

Figure 17. Most probable number of total coliforms per 100ml for the year 2003.

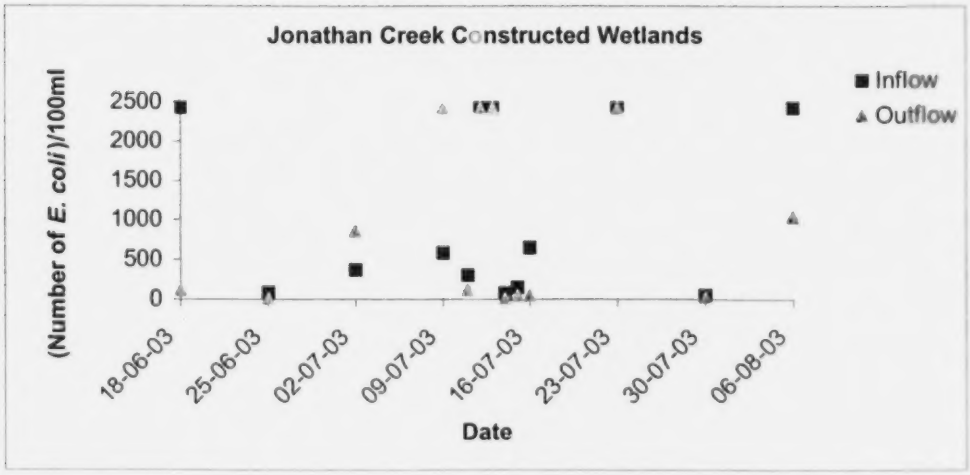

Figure 18. Most probable number of *E. coli* per 100ml for the year 2003.

From Octobre 25, 2004 the membrane filtration method was also used in an attempt to better quantify the bacterial counts (EPA 2002). The two methods often had a substantial amount of variance between the estimated bacterial counts, but they both showed similar reducing trends and efficiencies.

Macroinvertebrates

A total of six Surber samples for macroinvertebrates were collected in Jonathan Creek on October 7, 2003 from locations upstream and downstream of the outflow from the wetlands. Macroinvertebrates were identified to Family and the %ETP index was calculated and compared to Gorge Brook, a trout-bearing stream located at the boundary of the City of Moncton. We acknowledge the shortcomings of the Gorge Brook data in the 2003 analysis as it was taken in another year, though the watercourse is similar in size to Jonathan Creek. The same procedure was carried out in 2004, however, the samples were compared to Gorge Brook samples that were collected within a couple of days of each other. The 2004 Jonathan Creek samples had a considerable increase in %EPT at the downstream site compared to the upstream site and was higher than Gorge Brook in 2004 (Figure 19). This is the second indication that the wetlands are having a positive effect on water quality.

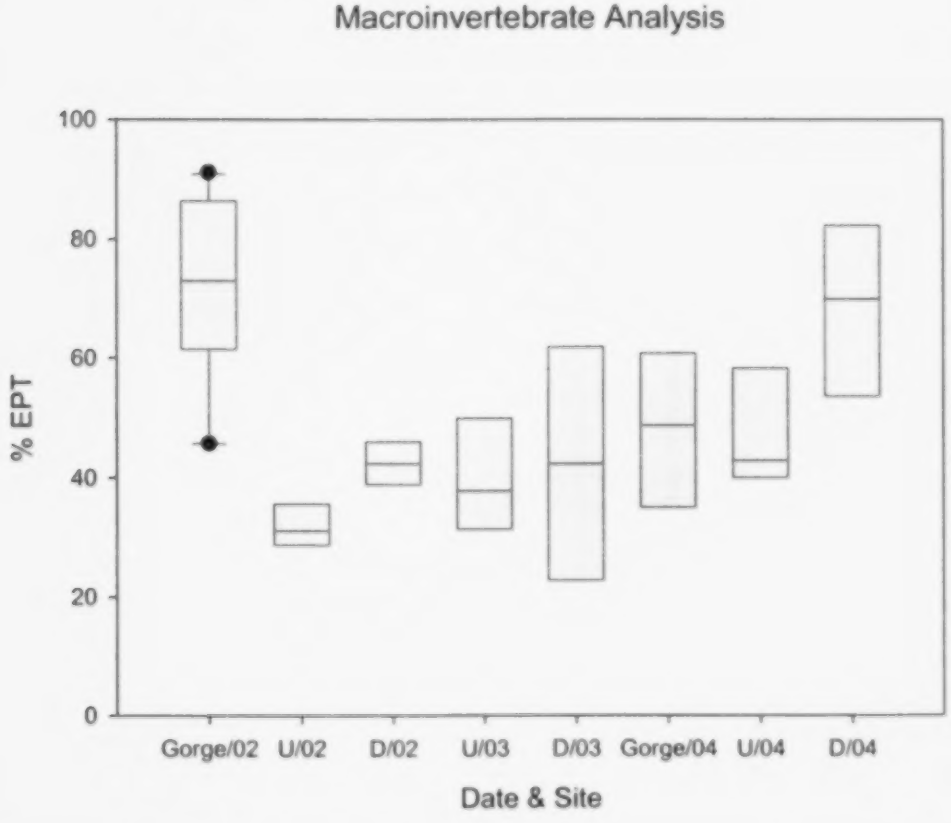

Figure 19. Percent EPT values for upstream (U) and downstream (D) sites in 2002 (02), 2003 (03) and 2004 (04) and Gorge Brook in 2002 and 2004. Note that the Gorge Brook 2002 data was based on 10 samples, while the rest of the data was based on six samples.

General conclusions

The constructed wetlands can be considered a success. However, inflow levels of cadmium and *E. coli* must be reduced as the size of the wetlands cannot be increased. This suggests a careful attention to levels of contaminants in the inflow versus the capacity of the wetlands to neutralize them. The wetlands must also be constructed to accept the volume of water resulting from storm events. In the event of a full breach of the berm, considerable, possibly contaminated, sediment could enter the receiving waters. Due to the presence of heavy metal contaminants in excess of the recommended guidelines found in this study, it is strongly recommended that sediments be tested at least every five years in the first settling pond and if necessary be removed and treated.

Appendix

Table 3. Water quality parameters measured during 2003 and 2004 within the wetlands and upstream and downstream of the outflow to Jonathan Creek.

Date	Site	Air Temperature (°C)	Water Temperature (°C)	Conductivity (µS)	pH	Oxygen (mg/L)	Turbidity (NTU)
12-Jun-03	Inflow	16.5	14.7	300	7.3	10.8	23.5
12-Jun-03	Middle	18.6	17.6	270	7.6	6.8	54
12-Jun-03	Outflow	17.4	17.1	190	7.8	6.9	151
12-Jun-03	Upstream	17.0	14.6	230	7.75	9.9	68.4
12-Jun-03	Downstream	17	14.4	270	7.8	9.6	77.8
18-Jun-03	Inflow	24.0	11.9	680	8.0	10.7	96.4
18-Jun-03	Middle	23.5	20.3	270	8.1	7.5	23.7
18-Jun-03	Outflow	23.6	17.8	260	8.6	10.3	16.4
18-Jun-03	Upstream	23.6	15.2	290	8.4	11.0	2.71
18-Jun-03	Downstream	23.7	14.6	290	8.3	11.6	15.0
25-Jun-03	Inflow	19.5	12.2	560	8.9	10.6	5.49
25-Jun-03	Middle	19.5	21.9	480	8.5	7.5	3.15
25-Jun-03	Outflow	19.6	21.0	440	8.6	6.3	3.35
25-Jun-03	Upstream	19.6	17.9	350	8.5	9.8	228
25-Jun-03	Downstream	19.7	16.9	320	8.5	10.5	163
2-Jul-03	Inflow	23	14.1	480	9.1	10.8	9.59
2-Jul-03	Middle	23	22.5	550	8.6	5.8	254
2-Jul-03	Outflow	23.1	21.7	500	8.5	5.1	425
2-Jul-03	Upstream	22.5	19.0	380	8.4	8.8	264
2-Jul-03	Downstream	22.5	18.0	380	8.4	9.7	523
9-Jul-03	Inflow	18.5	14.9	490	8.6	10.6	408
9-Jul-03	Middle	17.9	22.2	520	8.4	7.7	252
9-Jul-03	Outflow	19.6	21.1	510	8.3	5.3	273
9-Jul-03	Upstream	19.6	19.9	440	8.2	7.5	544
9-Jul-03	Downstream	19.7	17.9	420	8.2	8.5	386
11-Jul-03	Inflow	15.1	13.4	560	8.6	10.9	17.4
11-Jul-03	Middle	15.5	21.6	570	8.6	8.1	71.0
11-Jul-03	Outflow	15.5	20.5	550	8.5	6.0	90.0
11-Jul-03	Upstream	15.6	16.3	540	8.3	10.3	644
11-Jul-03	Downstream	15.6	15.8	540	8.4	9.8	644
12-Jul-03	Inflow	24.7	16.6	500	8.6	9.2	19.9
12-Jul-03	Middle	24.7	22.7	200	8.6	7.8	123.0
12-Jul-03	Outflow	24.8	19.9	250	8.4	5.8	134.0
12-Jul-03	Upstream	24.6	18.2	330	8.3	8.6	644.0
12-Jul-03	Downstream	24.6	17.2	360	8.4	11.6	60.3
13-Jul-03	Inflow	19.9	14.4	590	8.6	7.6	0.43
13-Jul-03	Middle	20.0	19.7	230	8.6	5.4	116.0
13-Jul-03	Outflow	20.0	18.4	220	8.6	2.8	66.0
13-Jul-03	Upstream	20.0	17.4	420	8.3	7.6	726.0
13-Jul-03	Downstream	20.0	16.1	450	8.4	9.9	857

Date	Site	Air Temperature (°C)	Water Temperature (°C)	Conductivity (µS)	pH	Oxygen (mg/L)	Turbidity (NTU)
14-Jul-03	Inflow	27.0	16.6	510	7.9	9.3	7.88
14-Jul-03	Middle	27.0	26.0	270	8.2	10.2	18.2
14-Jul-03	Outflow	27.0	25.6	250	8.4	2.0	644.0
14-Jul-03	Upstream	27.0	22.0	510	8.2	9.1	13.8
14-Jul-03	Downstream	27.0	20.2	500	8.3	10.3	18.1
16-Jul-03	Inflow	18.7	14.8	550	9.0	9.4	6.31
16-Jul-03	Middle	18.6	23.5	330	8.9	8.3	5.16
16-Jul-03	Outflow	18.7	21.7	270	8.8	7.3	1.68
16-Jul-03	Upstream	19.1	19.2	600	8.4	9.5	0.87
16-Jul-03	Downstream	19.0	17.6	590	8.6	9.6	4.39
23-Jul-03	Inflow	23.0	20.7	100	9.4	11.1	532
23-Jul-03	Middle	23.0	22.8	450	8.9	6.8	6.65
23-Jul-03	Outflow	23.0	22.7	410	9.2	6.0	13.8
23-Jul-03	Upstream	23.0	20.7	210	9.5	8.6	320
23-Jul-03	Downstream	23.0	20.6	170	9.7	8.9	385
30-Jul-03	Inflow	20.0	15.1	410	N/A	9.8	1.95
30-Jul-03	Middle	20.1	20.2	430	N/A	9.7	4.13
30-Jul-03	Outflow	20.0	19.6	360	N/A	8.7	1.63
30-Jul-03	Upstream	20.0	17.7	550	N/A	10.4	644.0
30-Jul-03	Downstream	20.0	16.1	530	N/A	9.7	4.65
6-Aug-03	Inflow	20.4	18.3	220	N/A	11.1	76.9
6-Aug-03	Middle	20.4	19.6	370	N/A	2.9	15.7
6-Aug-03	Outflow	20.4	19.8	380	N/A	4.6	3.34
6-Aug-03	Upstream	20.4	19.4	210	N/A	8.3	31.2
6-Aug-03	Downstream	20.5	18.6	300	N/A	8.8	90.5
13-Aug-03	Inflow	20.2	17.5	340	N/A	8.8	153.0
13-Aug-03	Middle	20.2	18.1	156	N/A	7.6	209.0
13-Aug-03	Outflow	20.3	18.7	203	N/A	9.9	35.0
13-Aug-03	Upstream	20.3	17.9	85	N/A	9.3	25.0
13-Aug-03	Downstream	20.3	17.8	15	N/A	9.9	39.0
20-Aug-03	Inflow	30.0	18.6	690	9.0	9.3	212
20-Aug-03	Middle	30.0	24.7	560	8.3	4.0	6.44
20-Aug-03	Outflow	30.0	23.7	410	8.3	3.9	3.83
20-Aug-03	Upstream	30.0	19.2	560	8.1	11.6	3.76
20-Aug-03	Downstream	30.0	20.1	580	7.9	6.1	64.2
27-Aug-03	Inflow	23.2	17.8	230	8.6	4.6	4.63
27-Aug-03	Middle	23.2	20.2	165	8.3	10.3	19.8
27-Aug-03	Outflow	23.4	20.3	550	8.6	9.0	1.75
27-Aug-03	Upstream	23.4	19.5	430	8.7	9.8	3.38
27-Aug-03	Downstream	23.3	19.8	440	8.6	10.1	7.12
3-Sep-03	Inflow	21.0	18.3	500	8.5	8.8	261
3-Sep-03	Middle	21.0	21.9	610	8.5	6.9	10.65
3-Sep-03	Outflow	21.0	21.7	630	8.5	10.5	2.60
3-Sep-03	Upstream	21.0	15.7	580	8.4	10.5	3.55
3-Sep-03	Downstream	21.0	15.8	620	8.4	12.4	3.67

Date	Site	Air Temperature	Water Temperature	Conductivity	pH	Oxygen	Turbidity
		(°C)	(°C)	(µS)		(mg/L)	(NTU)
23-Aug-04	Pipe	21.1	16.7	609	7.6	8.5	52.9
23-Aug-04	Inflow	24.7	16.8	583	7.8	8.8	38.9
23-Aug-04	Middle	24.6	22.8	166.5	6.6	4.7	46.9
23-Aug-04	Outflow	22.4	19.6	185	7.1	6.68	33.5
23-Aug-04	Downstream	22.7	16.4	438.2	7.6	9.14	18.1
23-Aug-04	Upstream	19.8	16.4	449.4	7.8	9.52	10.48
30-Aug-04	Pipe	22.2	19.1	273.6	7.7	8.94	289
30-Aug-04	Inflow	22.9	19.2	290.2	7.8	9.21	351
30-Aug-04	Middle	20.9	19.9	160.3	7.5	7.43	148
30-Aug-04	Outflow	22.1	20.2	351.5	7.2	7.17	19
30-Aug-04	Downstream	20.2	19	318.8	7.6	8.44	1035
30-Aug-04	Upstream	20.2	18.7	275.3	8.2	8.52	347
31-Aug-04	Pipe	24.4	20.2	179.3	7.6	8.82	170
31-Aug-04	Inflow	23.2	20.3	195.7	7.8	9.18	169
31-Aug-04	Middle	23.2	20.1	119.3	7.3	8.03	198
31-Aug-04	Outflow	22.5	20.2	154.7	7.1	7.57	143
31-Aug-04	Downstream	N/A	N/A	N/A	N/A	N/A	N/A
31-Aug-04	Upstream	N/A	N/A	N/A	N/A	N/A	N/A
1-Sep-04	Pipe	18.5	17.5	494.6	7.8	9.17	25.4
1-Sep-04	Inflow	18.8	17.6	498.2	8	9.57	27
1-Sep-04	Middle	23.4	23.2	155.5	7.2	5.46	90.7
1-Sep-04	Outflow	18.7	19.8	166.3	7.1	6.81	73.2
1-Sep-04	Downstream	18.7	17	183.4	7.4	9.12	75.3
1-Sep-04	Upstream	17.6	16.7	182.9	7.4	9.49	19.2
2-Sep-04	Pipe	13.4	16.4	597	8	9.11	13.5
2-Sep-04	Inflow	13.7	15.9	583	8.1	9.44	10.51
2-Sep-04	Middle	13.1	19.5	210.4	7.2	3.16	46.8
2-Sep-04	Outflow	13.1	17	230.9	7.1	6.13	36.7
2-Sep-04	Downstream	14.7	14.7	234.5	7.7	9.17	14.2
2-Sep-04	Upstream	13	14.3	228.7	7.6	9.91	10.3
7-Sep-04	Pipe	14.1	15.7	651	8.1	9.61	4.89
7-Sep-04	Inflow	14.1	15.2	640	8.1	9.64	2.39
7-Sep-04	Middle	16.1	16.7	296.8	8.4	11.94	9.86
7-Sep-04	Outflow	15	14.4	301.6	7.1	6.44	10.76
7-Sep-04	Downstream	16	13.2	322.8	7.8	9.85	6.67
7-Sep-04	Upstream	13.8	12.9	317.6	7.8	10.19	5.71
13-Sep-04	Pipe	12.8	15.7	656	7.9	8.96	22.4
13-Sep-04	Inflow	15.3	14.9	637	8.1	9.63	2.49
13-Sep-04	Middle	12.5	18	338.4	7.6	8.85	12.6
13-Sep-04	Outflow	15.3	15.9	355.5	7.3	6.45	5.79
13-Sep-04	Downstream	13.3	13.5	288.6	7.8	9.92	7.12
13-Sep-04	Upstream	14.6	13.4	284.5	7.8	9.96	7.82
20-Sep-04	Pipe	16.1	14.7	440	8.2	9.43	20
20-Sep-04	Inflow	14.2	13.9	440	8.2	9.86	8.5
20-Sep-04	Middle	14.2	13.4	220	7.9	8.83	45

Date	Site	Air Temperature (°C)	Water Temperature (°C)	Conductivity (µS)	pH	Oxygen (mg/L)	Turbidity (NTU)
20-Sep-04	Outflow	10.3	11.4	200	7.3	7.62	16
20-Sep-04	Downstream	10.5	9.8	200	7.8	11.08	7.7
20-Sep-04	Upstream	11.3	9.7	190	8	11.13	8.5
27-Sep-04	Pipe	17.4	14.5	140	8	9.91	19.3
27-Sep-04	Inflow	16.6	13.7	140	8.1	10.52	5.75
27-Sep-04	Middle	16.6	14.8	100	9	12.22	3.13
27-Sep-04	Outflow	14	13.6	100	7.4	8.11	6.3
27-Sep-04	Downstream	13.8	11.8	110	7.8	11.08	10.87
27-Sep-04	Upstream	15.3	11.9	110	7.9	11.18	5.7
4-Oct-04	Pipe	18.4	14.3	50	7.9	9.89	2.5
4-Oct-04	Inflow	15.3	13.9	40	8	10.34	2.1
4-Oct-04	Middle	14.1	13.6	40	8.8	8.76	4.9
4-Oct-04	Outflow	14.3	13	40	7.6	7.64	25
4-Oct-04	Downstream	14.4	11.7	30	7.8	10.45	2.6
4-Oct-04	Upstream	14	11.7	30	8	10.94	2.1
12-Oct-04	Pipe	14.2	12.7	220	7.6	10.88	95
12-Oct-04	Inflow	12.8	12.6	210	7.8	10.92	110
12-Oct-04	Middle	11.2	11.2	130	7.7	10.06	60
12-Oct-04	Outflow	11.3	11.1	160	7.4	10.26	60
12-Oct-04	Downstream	11.3	10.8	230	7.6	10.43	70
12-Oct-04	Upstream	11.8	10.6	270	7.6	10.65	70
18-Oct-04	Pipe	12.5	13	510	7.9	10.46	33
18-Oct-04	Inflow	12.2	12.3	580	8.1	10.83	23
18-Oct-04	Middle	8.8	12.5	330	7.6	3.87	39
18-Oct-04	Outflow	8.9	11	350	7.4	7.3	34
18-Oct-04	Downstream	9	9.2	190	7.6	11.36	7.6
18-Oct-04	Upstream	9.3	9	170	7.6	11.7	8
25-Oct-04	Pipe	14.7	12.3	680	8.1	8.85	85
25-Oct-04	Inflow	11.9	12.2	680	8.1	8.81	26
25-Oct-04	Middle	11.4	11.9	400	8.3	12.1	11
25-Oct-04	Outflow	10.7	9.1	530	7.4	11.38	13
25-Oct-04	Downstream	9.9	9.1	280	7.8	10.5	2.4
25-Oct-04	Upstream	10.4	9.2	270	7.9	10.55	2.6
1-Nov-04	Pipe	11.5	11.4	650	8.3	10.56	40
1-Nov-04	Inflow	10	11	660	8.3	11.04	23
1-Nov-04	Middle	7.3	8.5	560	7.8	9.38	36
1-Nov-04	Outflow	7.6	7	620	7.6	10.12	17
1-Nov-04	Downstream	7.2	7.4	330	7.9	12.56	10
1-Nov-04	Upstream	8.4	7.3	300	8.1	12.71	8.8
8-Nov-04	Pipe	5.4	6.5	140	8.4	14.45	110
8-Nov-04	Inflow	3.6	6.3	170	8.2	14.56	114
8-Nov-04	Middle	0.8	7.1	350	8.1	11.6	57.1
8-Nov-04	Outflow	1.9	5.7	450	7.9	12.33	30.7
8-Nov-04	Downstream	1.8	5.7	220	8.3	13.8	150
8-Nov-04	Upstream	2.3	5.9	210	8.2	13.81	148

Date	Site	Air Temperature	Water Temperature	Conductivity	pH	Oxygen	Turbidity
		(°C)	(°C)	(µS)		(mg/L)	(NTU)
15-Nov-04	Pipe	7	7.6	1120	7.8	11.73	20.6
15-Nov-04	Inflow	3	7.2	1140	7.8	12.08	18.9
15-Nov-04	Middle	0.4	2.6	360	7.7	5.17	19.9
15-Nov-04	Outflow	0.4	1.7	1010	7.5	10.01	16
15-Nov-04	Downstream	0.4	1.3	400	7.7	15.06	6.21
15-Nov-04	Upstream	2.7	1.2	380	7.8	15.31	6.18

Table 4. Nutrient and metal concentrations at all sites for years 2003 and 2004.

Date	Site	Inorganic Carbon	Nitrogen	Organic Carbon	Al	As	Cd	Cr	Co	Cu	Pb	Zn
		(mg/L)	(mg/L)	(mg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)
18/Jun/03	Inflow	28.8	11.88	11.1	1640	1.2	1.6	22.4	1.4	107	48.1	109.6
18/Jun/03	Middle	13.8	0.34	3.8	542	0.8	<0.1	1.3	0.4	6.1	1.4	10.3
18/Jun/03	Outflow	15.2	0.23	4.2	75.7	0.5	<0.1	0.4	0.1	1.8	0.2	2.4
18/Jun/03	Upstream	14.1	0.1	7.7	475	0.8	<0.1	1.1	0.3	5.7	1.1	9.3
18/Jun/03	Downstream	14.2	0.1	8.2	83.7	<0.5	<0.1	0.4	0.1	1.5	0.2	2.3
11/Jul/03	Inflow	26.8	0.82	7.3	582.3	<0.5	2.1	3.6	<1.0	33.5	11.2	123.3
11/Jul/03	Middle	21.3	0.23	5.7	375.4	<0.5	<1.0	2	<1.0	5.1	<1.0	14.1
11/Jul/03	Outflow	23	0.16	6.4	45.3	<0.5	<1.0	1.7	<1.0	4.2	<1.0	10.1
11/Jul/03	Upstream	24.3	0.3	4.4	37.7	<0.5	<1.0	2.2	<1.0	1.3	<1.0	4.9
11/Jul/03	Downstream	24.1	0.32	4.5	37.7	<0.5	<1.0	1.5	<1.0	1.3	<1.0	7.3
14/Jul/03	Inflow	23.6	3.635	4.9	NA	1.05	0.15	2.6	1.1	10.3	4.4	33.6
14/Jul/03	Middle	15.9	0.715	4.55	NA	1.25	0.15	2.05	1	7.7	3.55	24.7
14/Jul/03	Outflow	16.8	0.41	4.55	NA	1.25	0.25	3.8	1.9	11.9	7.2	43.45
14/Jul/03	Upstream	18.2	0.485	4.4	NA	1	0.3	4.35	2.25	8.7	7.4	37.5
14/Jul/03	Downstream	17.2	0.505	4.25	NA	1.2	0.2	5	2.45	7.35	6.7	33.15
16/Jul/03	Inflow	28	1.29	7.5	NA	NA	NA	NA	NA	NA	NA	NA
16/Jul/03	Middle	15.1	0.08	3.9	NA	NA	NA	NA	NA	NA	NA	NA
16/Jul/03	Outflow	15.9	0.94	4.5	NA	NA	NA	NA	NA	NA	NA	NA
16/Jul/03	Downstream	25.4	0.46	4.5	NA	NA	NA	NA	NA	NA	NA	NA
16/Jul/03	Upstream	26.3	0.48	5.1	NA	NA	NA	NA	NA	NA	NA	NA
30/Aug/04	Pipe	13.3	1.6	5.7	5231	1.4	0.2	6.7	2.8	18.2	12.9	80.5
30/Aug/04	Inflow	15.3	1.64	5.6	5813	1.5	0.3	6.1	2.9	17.4	12.3	68.1
30/Aug/04	Middle	7.7	0.78	4	3599	1.1	0.2	5	1.9	11	8.5	39.9
30/Aug/04	Outflow	20.1	0.27	5.4	426.8	1.4	<0,1	1.5	0.5	3.5	1.2	9.8
30/Aug/04	Upstream	13.7	1.05	6.2	6392	1	0.2	7.1	3.1	12.9	10.1	39.6
30/Aug/04	Downstream	14.4	1.25	10.9	10705	0.7	0.2	7.5	4.2	12.7	13.2	27.8
7/Sep/04	Pipe	31.8	0.76	5.4	64.7	0.7	<0,1	1.1	0.2	3.3	0.4	7.6

Date	Site	Inorganic Carbon	Nitrogen	Organic Carbon	Al	As	Cd	Cr	Co	Cu	Pb	Zn
		(mg/L)	(mg/L)	(mg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)
7/Sep/04	Inflow	25.2	0.66	4.5	59.1	0.7	<0,1	0.9	0.2	3.7	0.4	5.8
7/Sep/04	Middle	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
7/Sep/04	Outflow	17.6	0.22	5.3	402	1.1	<0,1	1.3	0.4	3.6	1	6.8
7/Sep/04	Upstream	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
7/Sep/04	Downstream	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
20/Sep/04	Pipe	29.4	0.75	5.9	305.4	0.9	0.2	1.9	0.3	5.1	2.2	21.2
20/Sep/04	Inflow	28.5	0.72	5.5	1431	1	<0,1	2.1	1	6.1	2.8	17
20/Sep/04	Middle	15.2	0.59	4.8	222.5	0.8	<0,1	0.7	0.3	4.8	1	12.5
20/Sep/04	Outflow	14.7	0.21	4	235.9	1	<0,1	1.5	0.2	3.4	0.8	5.9
20/Sep/04	Upstream	11.2	0.37	11.6	229.3	0.7	<0,1	0.7	0.1	<0,2	0.3	2.6
20/Sep/04	Downstream	11.3	0.39	11.7	193.6	0.7	<0,1	0.6	0.1	1.6	0.3	3.4
12/Oct/04	Pipe	14.3	0.98	6	1922	0.9	<0,1	3.9	1.5	13.1	6	44.4
12/Oct/04	Inflow	11.9	0.86	5.3	2568	2.1	0.8	5.4	2	14.9	10.7	82.1
12/Oct/04	Middle	8.1	0.54	3.5	1017	1	<0,1	1.8	0.8	6.9	2.7	21.3
12/Oct/04	Outflow	9.3	0.38	3	998.7	1	<0,1	2	0.8	6.6	2.6	21.6
12/Oct/04	Upstream	10	0.94	9.3	1287	0.7	<0,1	1.8	1.1	5.2	2.4	16.8
12/Oct/04	Downstream	9.8	0.71	9	1234	0.7	<0,1	1.8	1	5.1	2.3	16
25/Oct/04	Pipe	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
25/Oct/04	Inflow	30.7	0.47	5.8	578.2	1	0.5	1.6	0.5	12.5	3.2	38.6
25/Oct/04	Middle	21.6	0.18	7.3	204.9	1.4	<0,1	0.7	0.2	5.2	0.6	5.6
25/Oct/04	Outflow	27.4	0.14	7.9	135.9	1.4	<0,1	0.6	0.2	3.6	0.4	5.7
25/Oct/04	Upstream	12.4	0.2	8.5	84.1	0.5	<0,1	<0,4	0.1	1.8	0.2	1.5
25/Oct/04	Downstream	12.4	0.19	8.9	76.9	0.5	<0,1	<0,4	0.1	1.8	0.2	1.9
8/Nov/04	Pipe	11.4	0.39	4.2	3171	0.7	0.1	5	2.2	13.7	7.7	45.8
8/Nov/04	Inflow	11.4	0.4	4.2	4071	0.8	0.1	5.4	2.8	19.1	8.9	55.3
8/Nov/04	Middle	15.4	0.69	4.2	1343	0.7	<0,1	2.3	1	8.4	3.7	28.9
8/Nov/04	Outflow	20	0.7	6.7	725.4	0.8	<0,1	1.7	0.5	6.1	1.9	14.3
8/Nov/04	Upstream	9.1	0.25	8.5	2989	0.6	<0,1	3.1	1.9	7.2	4.6	27.3
8/Nov/04	Downstream	9.2	0.29	7.7	2578	0.6	<0,1	3.2	1.9	6.8	4.2	26.3

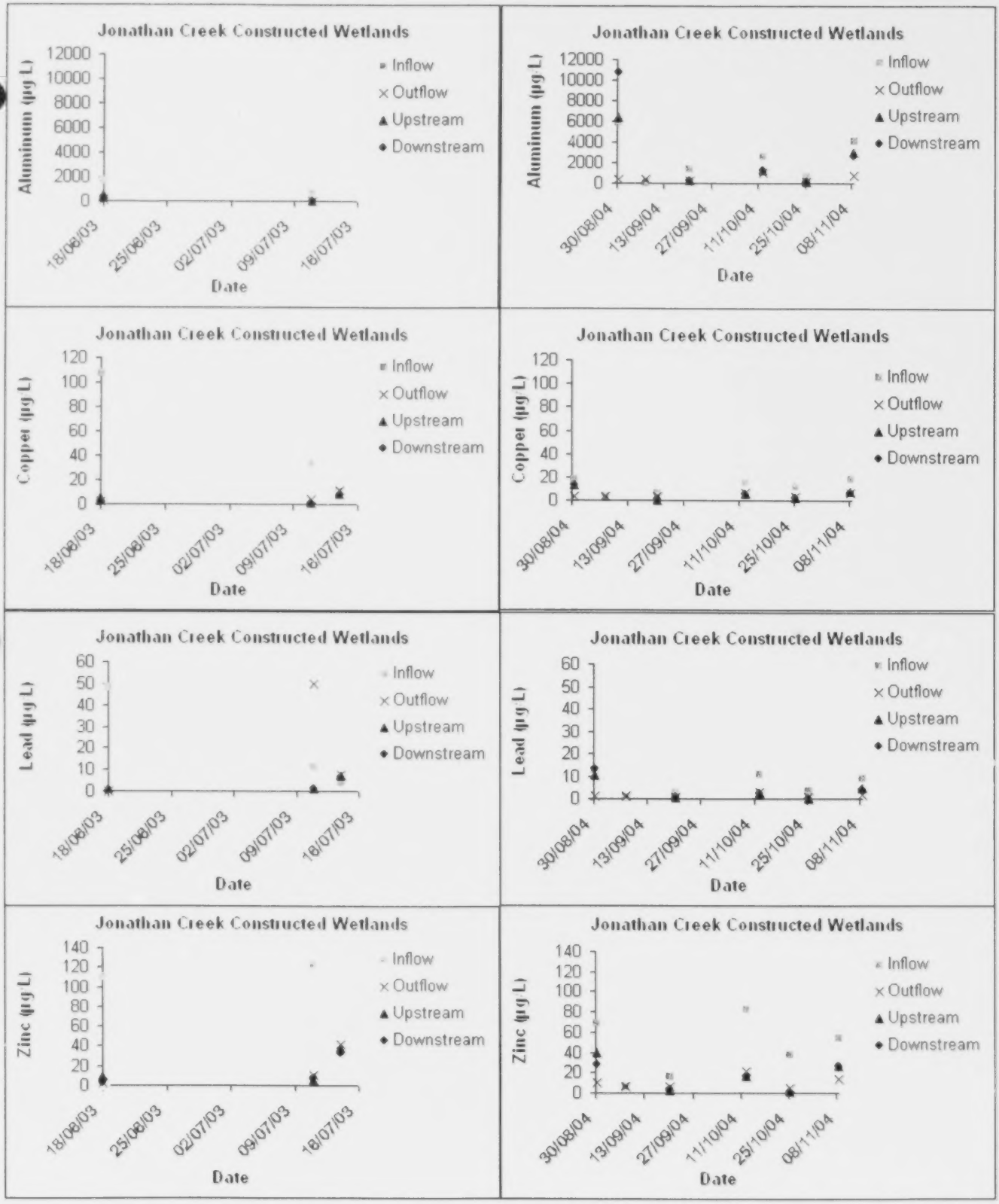

Figure 12. Metal graphs for 2003 and 2004.

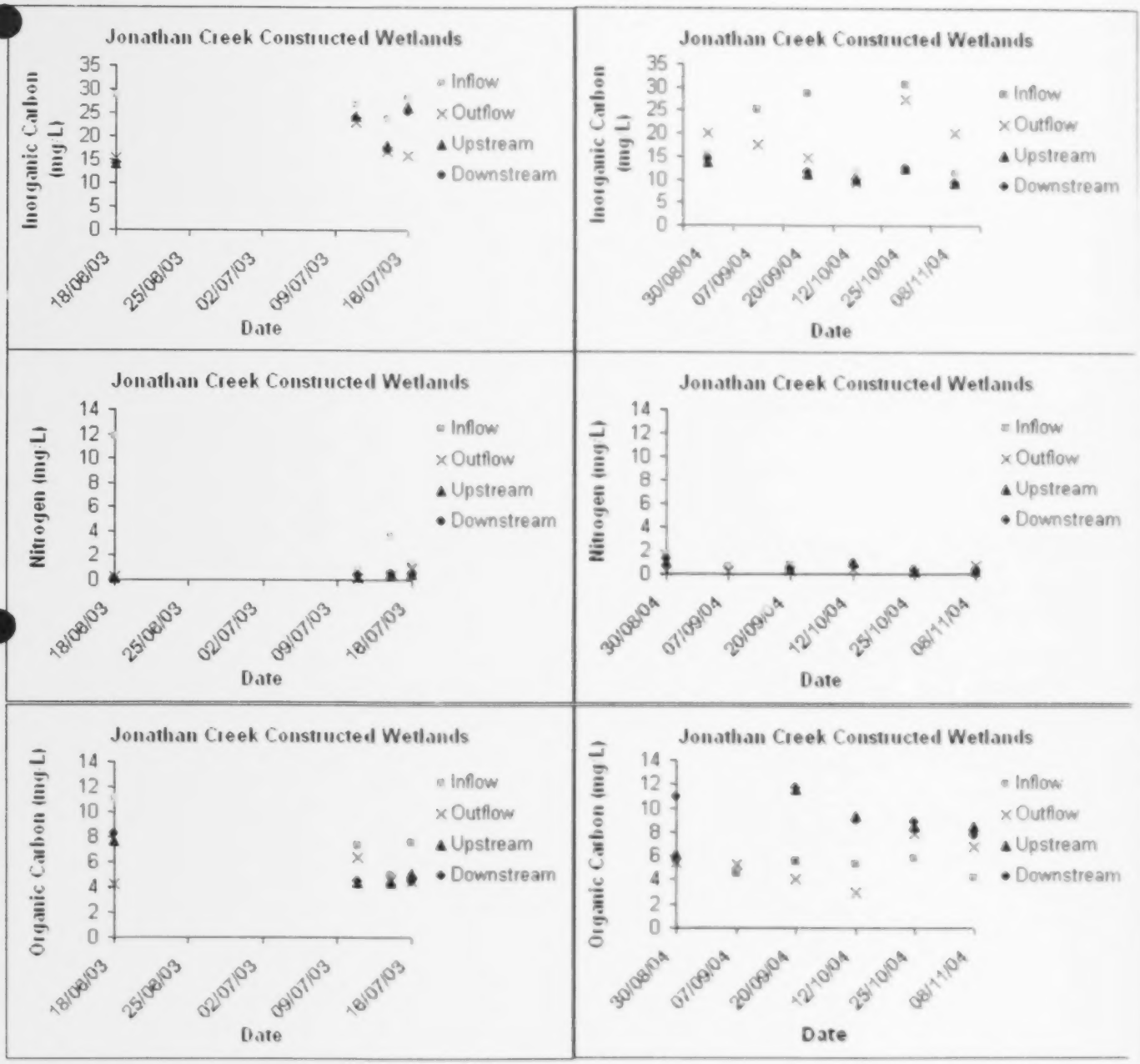

Figure 13. Nutrient graphs for 2003 and 2004.

Table 5. Most probable number of total coliforms and *E. coli* per 100 ml of water, based on the Coli Plate method.

		Coliforms	E. coli
Date	Site	MPN/100ml	MPN/100ml
18-Jun-03	Inflow	289	>2424
	Middle	263	219
	Outflow	114	114
	Downstream	127	46
	Upstream	83	161
25-Jun-03	Inflow	403	83
	Middle	289	213
	Outflow	654	11
	Downstream	489	36
	Upstream	619	33
02-Jul-03	Inflow	>2424	375
	Middle	>2424	1370
	Outflow	>2424	858
	Downstream	>2424	2424
	Upstream	>2424	1038
09-Jul-03	Inflow	>2424	587
	Middle	>2424	798
	Outflow	>2424	>2424
	Downstream	>2424	1696
	Upstream	>2424	>2424
11-Jul-03	Inflow	>2424	308
	Middle	>2424	1174
	Outflow	>2424	119
	Downstream	>2424	59
	Upstream	>2424	110
12-Jul-03	Inflow	>2424	>2424
	Middle	>2424	>2424
	Outflow	>2424	>2424
	Downstream	>2424	>2424
	Upstream	>2424	>2424
13-Jul-03	Inflow	248	>2424
	Middle	>2424	>2424
	Outflow	>2424	>2424
	Downstream	>2424	>2424
	Upstream	>2424	>2424
14-Jul-03	Inflow	>2424	79
	Middle	>2424	43
	Outflow	>2424	11
	Downstream	>2424	127
	Upstream	>2424	102
15-Jul-03	Inflow	>2424	151
	Middle	>2424	25
	Outflow	>2424	49

		Coliforms	E. coli
Date	Site	MPN/100ml	MPN/100ml
	Downstream	>2424	219
	Upstream	>2424	206
16-Jul-03	Inflow	>2424	654
	Middle	>2424	52
	Outflow	>2424	52
	Downstream	>2424	119
	Upstream	>2424	206
23-Jul-03	Inflow	>2424	>2424
	Middle	>2424	>2424
	Outflow	>2424	>2424
	Downstream	>2424	>2424
	Upstream	>2424	>2424
30-Jul-03	Inflow	>2424	52
	Middle	>2424	110
	Outflow	>2424	28
	Downstream	>2424	375
	Upstream	>2424	226
06-Aug-03	Inflow	>2424	>2424
	Middle	>2424	>2424
	Outflow	>2424	1038
	Downstream	>2424	>2424
	Upstream	>2424	>2424
23-Aug-04	Pipe	1370	219
	Inflow	619	328
	Middle	740	194
	Outflow	188	110
	Downstream	255	136
	Upstream	489	350
30-Aug-04	Pipe	>2424	>2424
	Inflow	>2424	>2424
	Middle	>2424	>2424
	Outflow	>2424	>2424
	Downstream	>2424	>2424
	Upstream	>2424	>2424
31-Aug-04	Pipe	>2424	>2424
	Inflow	2424	2424
	Middle	1696	1696
	Outflow	1370	1370
	Downstream	N/A	N/A
	Upstream	N/A	N/A
01-Sep-04	Pipe	1696	938
	Inflow	>2424	1370
	Middle	>2424	1370
	Outflow	>2424	794
	Downstream	>2424	1696
	Upstream	>2424	1696

		Coliforms	E. coli
Date	Site	MPN/100ml	MPN/100ml
02-Sep-04	Pipe	1696	489
	Inflow	>2424	388
	Middle	2424	132
	Outflow	2424	136
	Downstream	1370	434
	Upstream	2424	534
07-Sep-04	Pipe	>2424	233
	Inflow	1696	83
	Middle	>2424	43
	Outflow	858	19
	Downstream	1370	188
	Upstream	1370	151
13-Sep-04	Pipe	>2424	451
	Inflow	>2424	226
	Middle	1174	22
	Outflow	619	36
	Downstream	1370	182
	Upstream	>2424	132
20-Sep-04	Pipe	>2424	362
	Inflow	>2424	308
	Middle	>2424	206
	Outflow	>2424	102
	Downstream	1174	166
	Upstream	2424	119
27-Sep-04	Pipe	>2424	362
	Inflow	>2424	213
	Middle	>2424	3
	Outflow	587	36
	Downstream	2424	141
	Upstream	1696	76
04-Oct-04	Pipe	>2424	240
	Inflow	>2424	194
	Middle	>2424	87
	Outflow	>2424	39
	Downstream	1038	25
	Upstream	938	43
12-Oct-04	Pipe	>2424	>2424
	Inflow	>2424	>2424
	Middle	>2424	>2424
	Outflow	>2424	>2424
	Downstream	>2424	>2424
	Upstream	>2424	>2424
18-Oct-04	Pipe	>2424	2424
	Inflow	>2424	403
	Middle	1370	194
	Outflow	>2424	308

		Coliforms	E. coli
Date	Site	MPN/100ml	MPN/100ml
	Downstream	>2424	255
	Upstream	1696	166
21-Oct-04	Pipe	>2424	>2424
	Inflow	>2424	>2424
	Middle	938	5
	Outflow	1038	62
	Downstream	1696	102
	Upstream	1038	83
25-Oct-04	Pipe	>2424	>2424
	Inflow	>2424	90
	Middle	619	22
	Outflow	1038	39
	Downstream	740	72
	Upstream	740	36
01-Nov-04	Pipe	>2424	271
	Inflow	>2424	271
	Middle	>2424	206
	Outflow	>2424	83
	Downstream	>2424	>2424
	Upstream	>2424	2424
08-Nov-04	Pipe	>2424	>2424
	Inflow	>2424	>2424
	Middle	>2424	938
	Outflow	1696	151
	Downstream	>2424	858
	Upstream	>2424	1038
15-Nov-04	Pipe	>2424	1174
	Inflow	>2424	1038
	Middle	619	3
	Outflow	2424	106
	Downstream	1696	72
	Upstream	>2424	106

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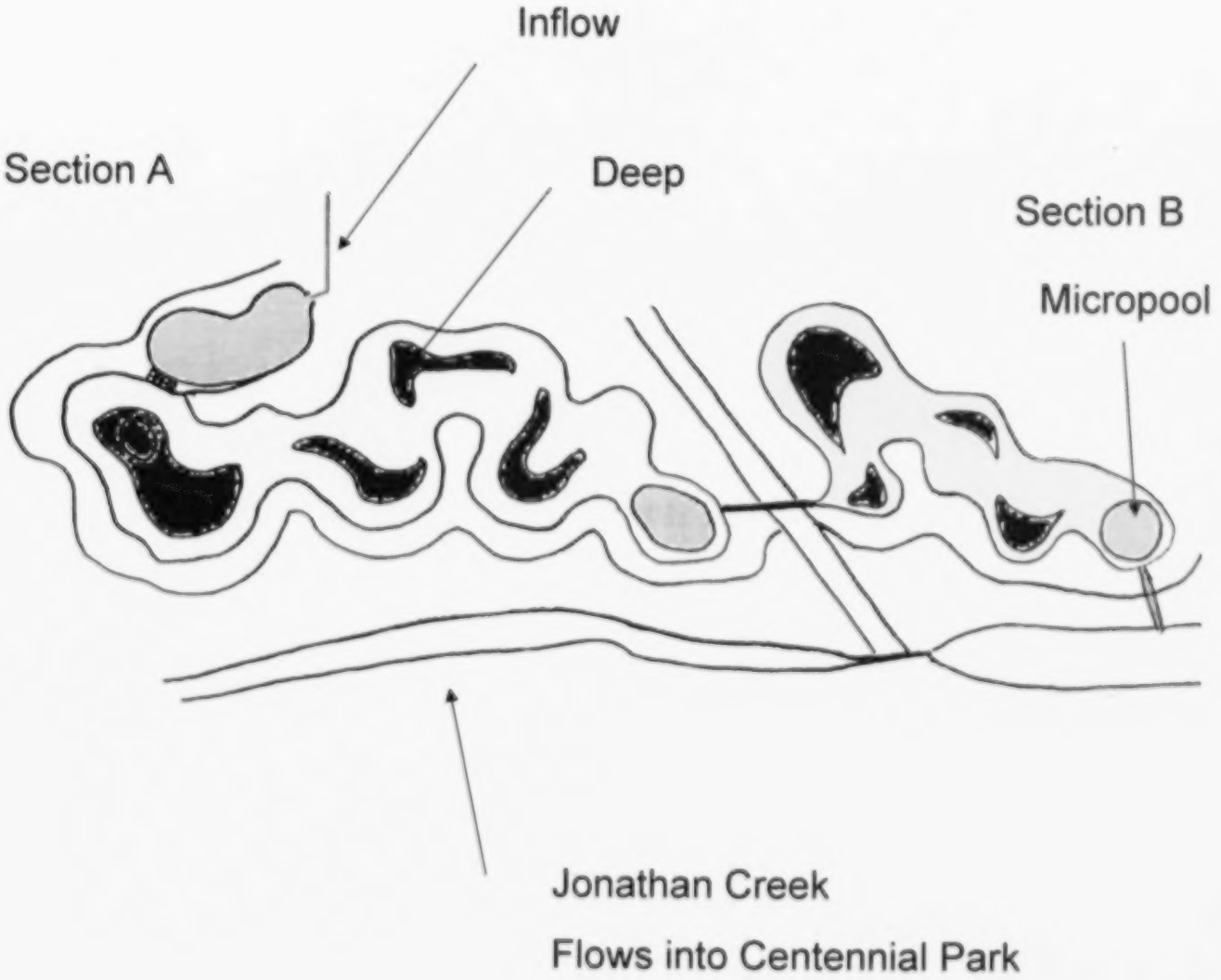
Using constructed wetlands to treat stormwater

New Nouveau
Brunswick

Your Environmental Trust Fund at Work
Votre Fonds en fiducie pour l'environnement au travail

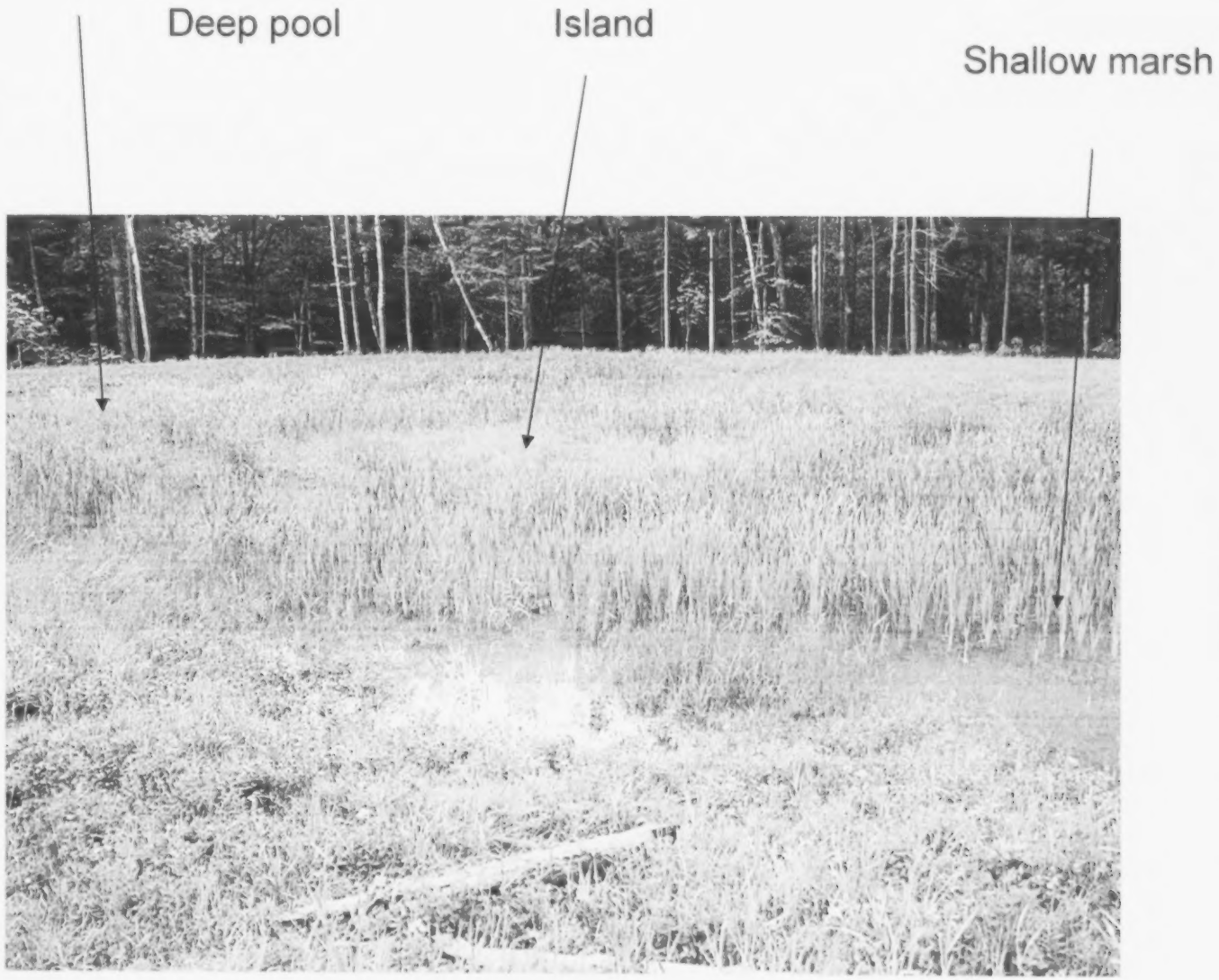
Dr. Alyre Chiasson
Département de biologie
Université de Moncton

The wetlands



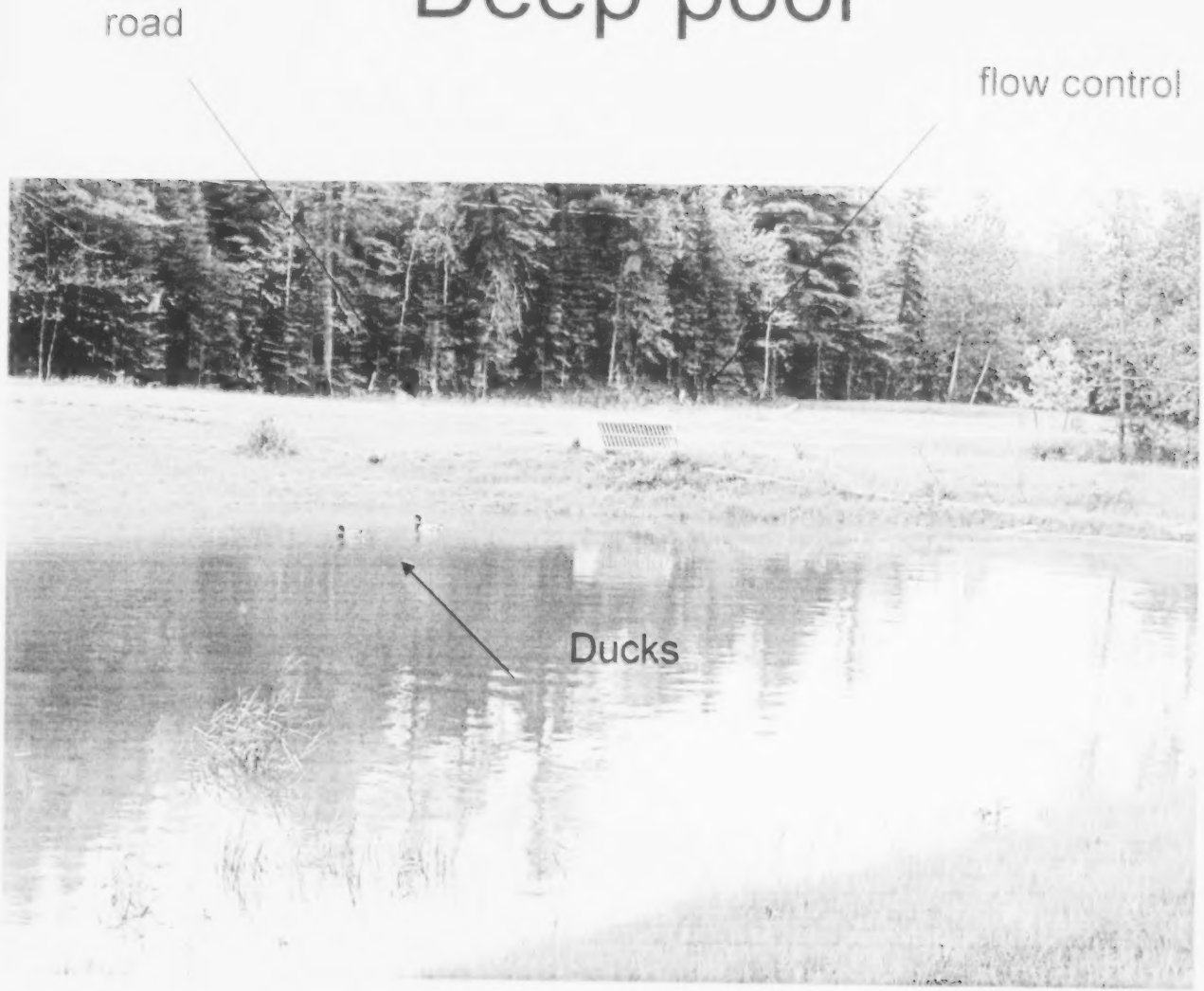
Inflow

First pool (settling)


Deep pool
Island
Shallow marsh

First pool
Third deep marsh pool

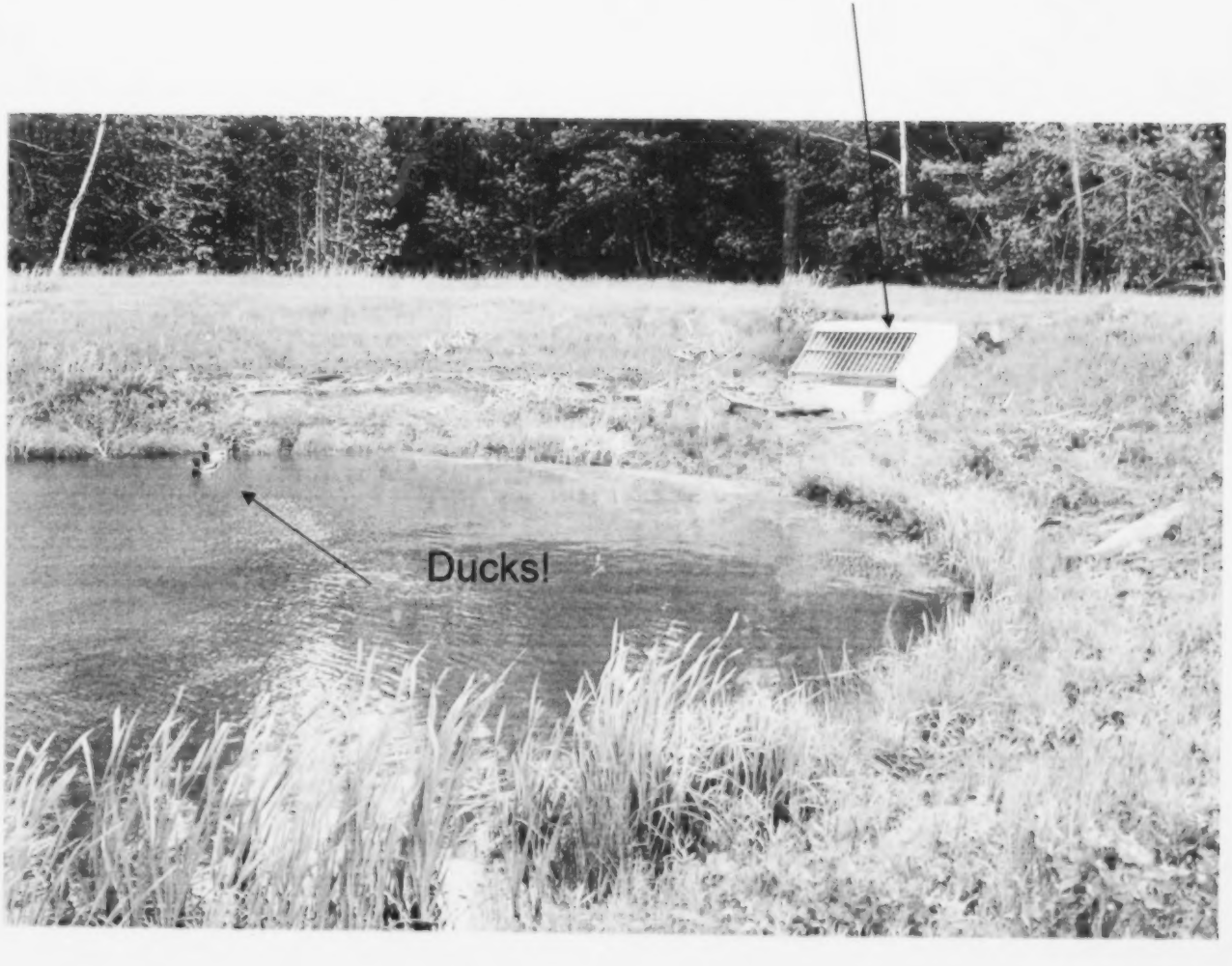
Deep pool



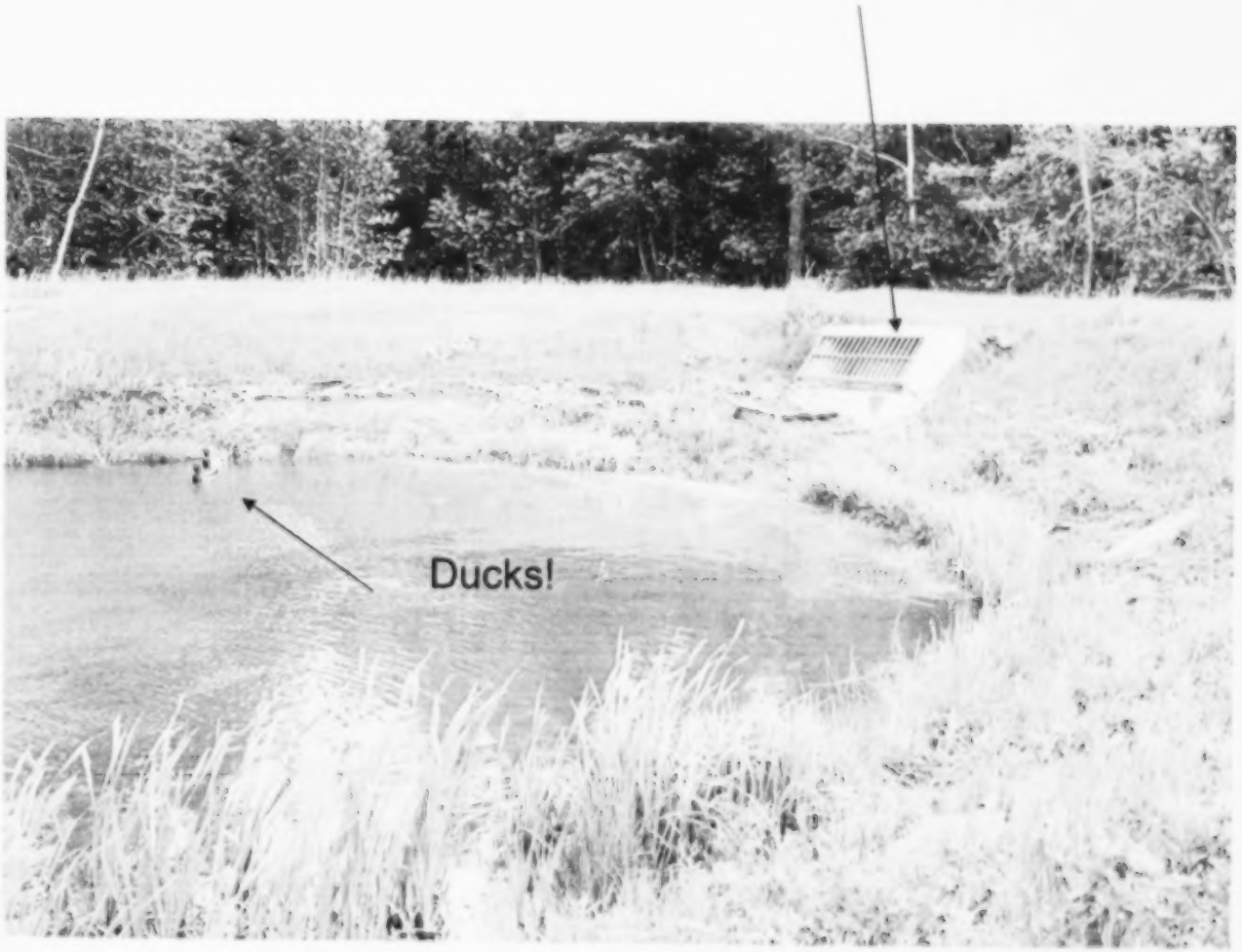
Deep marsh
(Section B)

Section B looking towards the road

Outflow structure



Outflow structure



Outflow into Jonathan Creek

Downstream from outflow

Upstream from outflow

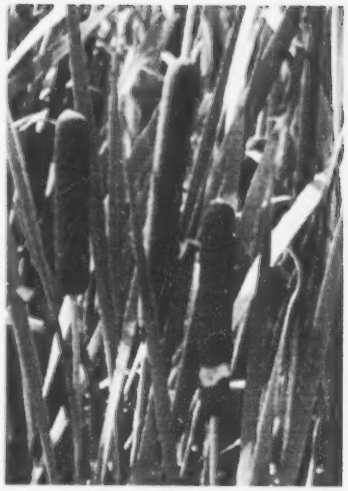
Erosion delta at inflow

Overflow during 2004 storm event

Flooding during storm event in 2004

Inflow across the forest floor during flood event in 2004

Entry of water into the first pond during storm event in 2004



Wetland vegetation

Vegetation progression

Vegetation progression

Open house

Constructed wetlands to treat storm sewer water
L'utilisation des terres humides pour le traitement des eaux pluviales
Un partenariat entre la Ville de Moncton, le Service canadien de la faune et l'Université de Moncton
A partnership between the City of Moncton, the Canadian Wildlife Service and the Université de Moncton